2 p

from IEEE Proc., Reprinted from
~~The Proceedings of the IEEE~~, ~~Vol.~~ 51, ~~No.~~ 6, June 1963

N63 22877

Code none

JPL Tech~~nical~~ Rep~~ort~~ ~~No.~~ 32-432

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(NASA CR 52020;

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June 1963 2 p 3 refs Repts.

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This paper presents results of one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology, under Contract ~~No.~~ NAS 7-100 sponsored by the National Aeronautics and Space Administration.

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JET PROPULSION LABORATORY

CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA

June 1963

Dual-Cavity Maser Used in Mars Radar Experiment*

A dual-cavity ruby maser operating at 2388 Mc has been used on an 85-ft diameter paraboloidal antenna at the Goldstone Tracking Station, (a station of the NASA /JPL Deep Space Instrumentation Facility) for planetary radar experiments. In the fall of 1962, a transmitter with 13-kw power output was used to study Venus.[1] Transmitter power was subsequently increased to 100 kw and echoes were received from Mars[2] in January and February, 1963. A Cassegrainian[3] antenna configuration made it possible to achieve a total system temperature of around 40°K (antenna pointed at zenith) as shown in Table I. The detected signal level of the Mars echo was of the order of −180 dbm.

The principal advantage of the multiple cavity maser is the improved gain stability over a single cavity unit operating with the same total gain.

The following relation is readily derived as the ratio of fractional gain variation ($\delta G/G$) for a n-stage maser as compared with a single-stage cavity maser operating with same total gain G_0:

$$\rho_n = \sqrt{n}\, G_0^{(1-n)/2n}. \tag{1}$$

For $n=2$,

$$\rho_2 = \frac{\sqrt{2}}{G_0^{1/4}}. \tag{2}$$

For a total gain of 34 db, the improvement factor is around 5. The above equations apply for identical stages with isolation between stages as shown in Fig. 1.

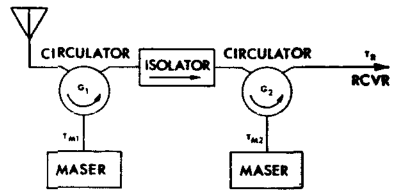

Fig. 1—Microwave circuit for dual cavity maser.

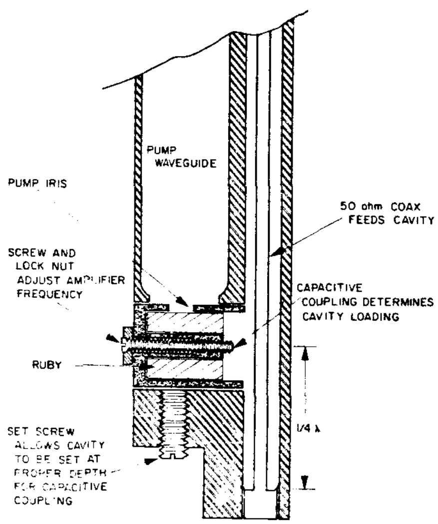

Fig. 2—Cross-sectional view of one of two identical maser units.

The bandwidth of 2.5 Mc was more than adequate for the radar experiments. Indeed, even with this narrow bandwidth, the black body radiation from Venus was detectable without a switching radiometer; however, the thermal radiation from Mars was much too weak to be discernible.

The equivalent noise temperature for the dual cavity maser is given by

$$T_s = T_{m1} + \frac{T_{m2}}{G_1} + \frac{T_r}{G_1 G_2}, \tag{3}$$

where

T_s = equivalent system noise temperature and other quantities on the right-hand side of (3) are defined in Fig. 1.

This shows a degradation in noise performance for the dual cavity maser, but the extra term (2nd term is absent for a single cavity maser) can be made negligible for high gain.

Fig. 2 shows a cross-sectional view of one of the two identical stages employed. Liquid helium was kept out of the structure for added stability. Cryogenic fluids were replenished daily, and, with a little care, the maser could be kept in continuous operation for many months.

TABLE I
PERFORMANCE SUMMARY FOR MASER SYSTEM

Frequency	Gain	BW	T_m	T_{ant}	$T_{w/g}$	T_{Total}	T_{Bath}
2388 Mc	34 db	2.5 Mc	20°±1	11°±1	8°±1	39°±3°K	4.2°K

The authors are grateful to the directors of the Planetary Radar Program, R. Stevens and W. K. Victor, for permission to publish this note separately from the Mars Report,[2] and to W. K. Rose of the Columbia Radiation Laboratory for a fruitful discussion on multiple cavity masers sometime ago.

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* Received March 11, 1963. This paper represents one phase of research carried out at the Jet Propulsion Laboratory, Pasadena, Calif., under contract No. NAS 7-100, sponsored by the National Aeronautics and Space Administration.

[1] R. L. Carpenter and R. M. Goldstein, "1962 JPL Venus radar experiment," *Science*, vol. 139, p. 910; March 8, 1963. See also: W. K. Victor and R. Stevens, "The 1961 JPL Venus radar experiment," IRE TRANS. ON SPACE ELECTRONICS AND TELEMETRY, vol. SET-8, pp. 84–97; June, 1962.

[2] 1963 JPL Mars Radar Experiment, to be published.

[3] P. Potter, "The application of the Cassegrainian principle to ground antennas for space communication," IRE TRANS. ON SPACE ELECTRONICS AND TELEMETRY, vol. SET-8, pp. 154–158; June, 1962.

Reprinted from the PROCEEDINGS OF THE IEEE
VOL. 51, NO. 6, JUNE, 1963

PRINTED IN THE U.S.A.